# INLET STABILIZATION: A CASE STUDY AT MOUTH OF COLORADO RIVER, TEXAS

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**Abstract**: The Mouth of Colorado River (MCR) is a federally authorized shallow draft navigation channel located in Matagorda County, TX. A weir jetty system was constructed at the MCR in the early 1980s to stabilize the inlet and provide access to the Gulf of Mexico. The weir jetty configuration has proven to be inefficient, requiring 450,000 $m^3$ of dredging annually to maintain the navigation channel, twice the design estimate. A new east jetty was installed at the MCR this year to more efficiently stabilize the inlet. Initial observations indicate that the new jetty configuration is fulfilling its role; the inlet current during construction scoured a narrow navigable channel along the west jetty. This paper discusses the history, engineering modifications, and implications for inlet stability at the MCR.

## Introduction

The Mouth of Colorado River (MCR) is a federally authorized shallow draft navigation channel located south of Matagorda and Bay City, Matagorda County, TX (Figure 1). The MCR is positioned west of the flood relief inlet, Mitchells Cut, dredged in 1989, and east of the Matagorda Ship Channel, constructed in 1966. This section of the Texas Coast has been modified extensively since the early 1900s, including diversion of the Brazos River in 1929 and multiple diversions of the Colorado River. A weir jetty system was constructed at the MCR in the early 1980s to stabilize the inlet and provide access to the Gulf of Mexico (Gulf); however greater-than-anticipated transport and landward bypassing of the impoundment basin necessitated frequent dredging to maintain the channel. A new east jetty was installed at the MCR this year to more efficiently stabilize the inlet. A more complete list of major engineering modifications within the region is included in Table 1.

Tides are predominantly diurnal with less than 0.5 m range in the Gulf and less in the bays. Astronomical tides are often dominated by strong wind on the Texas coast; wind-dominated tides often result in the fastest currents through a Texas inlet, controlling its stability (Kraus 2007). Average wave height offshore is less than 1.5 m (Kraus *et al* 2008) with extreme waves during tropical storms

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| 14. ABSTRACT<br>**The Mouth of Colorado River (MCR) is a federally authorized shallow draft navigation channel located in Matagorda County, TX. A weir jetty system was constructed at the MCR in the early 1980s to stabilize the inlet and provide access to the Gulf of Mexico. The weir jetty configuration has proven to be inefficient requiring 450,000 m3 of dredging annually to maintain the navigation channel, twice the design estimate. A new east jetty was installed at the MCR this year to more efficiently stabilize the inlet. Initial observations indicate that the new jetty configuration is fulfilling its role; the inlet current during construction scoured a narrow navigable channel along the west jetty. This paper discusses the history engineering modifications, and implications for inlet stability at the MCR.** | | | |
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capable of episodic transport of large volumes of sediment. Net longshore transport in the region is directed to the west, evidenced by spit growth at the MCR and the San Bernard River Mouth (SBRM), 60 km to the east. Kraus and Lin (2002) report that the SBRM migrated westward at about 0.36 m/day from 1989 to 1995, and about 0.49 m/day from 1995 to 2001. The increased rate is attributed to reworking of large volumes of sediment transported downriver to the Brazos River Delta during the 1992 flood.

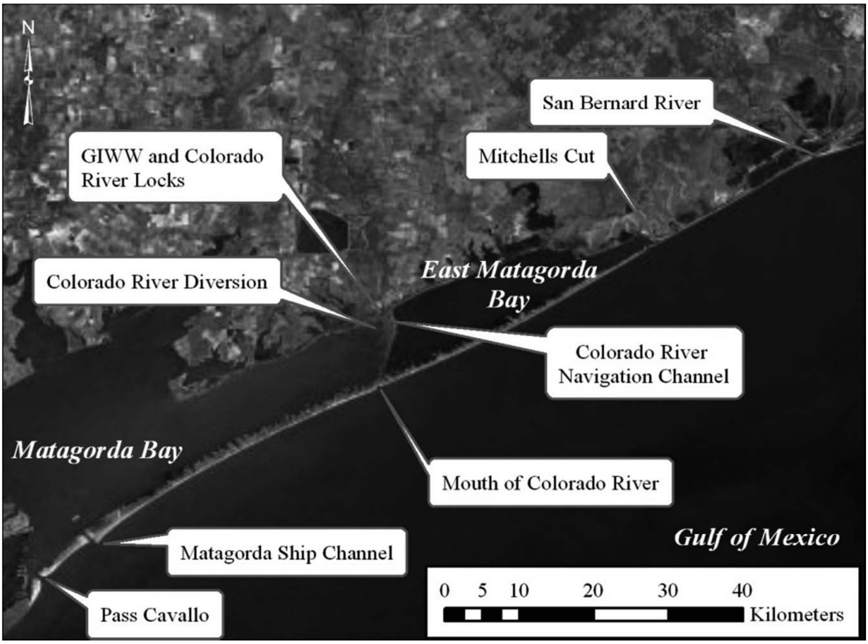


Fig. 1. Location map for region including the MCR

Figure 2 shows a 2008 aerial photograph of the SBRM with historical shorelines traced from aerial photographs overlaid (shoreline position prior to 2001 described in Gibeaut *et al* 2000). The SBRM was positionally stable until about 1984, after which continued development of the new Brazos River Delta caused the updrift shoreline to prograde to a point that net westward longshore transport destabilized inlet location. The inlet continued to migrate to the west until friction and drought reduced flow enough to cause closure in 2008. A new channel was dredged in 2009 to relocate the SBRM eastward to its historical location. Analysis of aerial photographs since construction indicates that the channel has continued to migrate westward at about 0.3 m/day. Net longshore sediment transport in the area can be inferred to be from east to west based on migration of the SBRM.

Table 1. Partial list of construction activities within region of the Mouth of Colorado River

| Year | Activity |
|---|---|
| 1929 | Removal of a log jam on Colorado River allowed delta to prograde across Matagorda Bay. |
| 1929 | Brazos River diverted from Freeport to present discharge location. |
| 1934 | Channel dredged to allow Colorado River to discharge directly to Gulf. |
| 1941 | Gulf Intracoastal Waterway construction complete in area. |
| 1954 | Colorado River locks constructed. |
| 1966 | Matagorda Ship Channel and jetties constructed. |
| 1984 | Original Mouth of Colorado River jetties constructed. |
| 1989 | Mitchells Cut dredged open to East Matagorda Bay to provide flood relief. |
| 1992 | Colorado River diverted into Matagorda Bay. |
| 2003 | Sediment training structure constructed between MCR jetties. |
| 2010 | New east jetty constructed at MCR. |

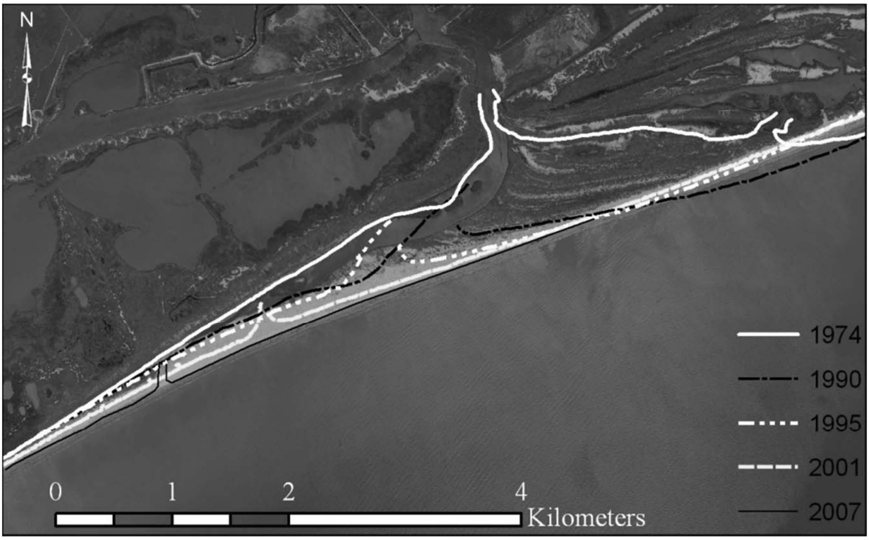


Fig. 2. Historical shoreline position near San Bernard River (Aerial photograph date: 9/4/2008)

**Inlet Processes Prior to Jetty Construction (1900 – 1984)**

Prior to the 1920s, a log raft on the Colorado River, developed over 100s of years, forced the Colorado River to discharge into various locations including Matagorda Bay, Caney Creek, and the Brazos River. After the raft was cleared in 1929, floods carried large volumes of sediment and logs into Matagorda Bay creating a delta across the Bay which connected to Matagorda Peninsula. This new configuration led to increased flooding of Bay City; to relieve flooding, a channel was dredged across the delta to the Gulf in 1934 (Kraus *et al* 2008). Creation of the new channel, later to be named the Colorado River Navigation Channel (CRNC), was the first time the river had discharged directly to the Gulf in recent history.

During preparation of the 1977 General Design Memorandum (GDM) for the original weir jetty system, net transport was estimated to be 230,000 $m^3$/year to the west with negligible transport to the east (U.S. Army Corps of Engineers (USACE) 1977). Estimates of transport at the MCR have been made by others since and range as high as 510,000 $m^3$/year for net westward transport and over 670,000 $m^3$/year gross transport (Kraus *et al* 2008).

Figure 3 shows historical shorelines overlaid on a 1987 aerial taken a few years after jetty construction. Westward net transport caused spit growth and channel migration to the west at the MCR (evident in shoreline positions plotted in Figure 3), similar to migration observed at the SBRM. Between 1937 and 1956, the spit grew westward 340 m; however, maintenance dredging was conducted from 1953-1954 which would influence morphology.


Fig. 3. MCR shoreline position 1937 - 1987 (Aerial photograph date: 3/4/1987)

Shoreline change rates directly to the east and west of the MCR were estimated by Morton *et al* (1976) through analysis of aerial photographs and charts, summarized in Table 2. Negative values in Table 2 indicate shoreline recession, and positive values indicate advance. The results show greater rates of recession on the downdrift side of the inlet.

Table 2. Incremental shoreline change rates prior to jetty construction (from Morton *et al* 1976)

| Location | Rate (m/year) | | | |
|---|---|---|---|---|
| | 1857-1937 | 1937-1956 | 1956-1965 | 1965-1974 |
| East of MCR | <-0.3 | 1.55 | -0.85 | -3.38 |
| West of MCR | -0.94 | -3.90 | 14.39 | -12.71 |

**Inlet Processes After Jetty Construction (1984 – Present)**

Shoaling in the Gulf Intracoastal Waterway (GIWW) prompted initial USACE involvement in stabilizing the inlet. However, USACE interests also include traffic at the Colorado River Locks, environmental stewardship of Matagorda Bay, and creation of a reliable shallow draft navigation channel. Those interests prompted construction of the weir jetty system at MCR in the early 1980s to stabilize the shallow draft navigation channel.

The west jetty followed a traditional stone design, but the east jetty included a 300 m long weir section at its landward end. The design included a 10 m deep impoundment basin to trap sand transported over the weir before it reached the navigation channel. Then sand could be dredged and bypassed without interrupting navigation. Major project design features are identified in Figure 4 along with shoreline position from 1991 – 2000.

The jetties were designed when weir jetty technology was being developed. At that time, weir jetties seemed to be a promising new technology that would reduce navigation channel downtime and jetty cost, while conveniently storing sand for future use and easy dredging in the lee of the offshore portion of the east jetty. Operational experience has since revealed the practical limitations of this technology, with most constructed projects being deemed unsuccessful.

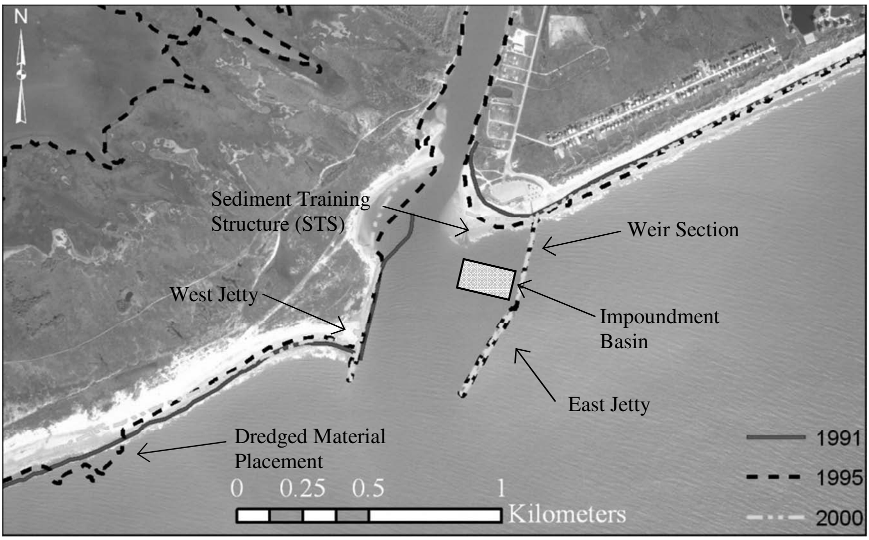


Fig. 4. MCR shoreline position 1991 – 2003 (Aerial photograph date: 12/18/2003)

Actual longshore transport rates observed after construction were about twice as much as predicted in the 1977 GDM, requiring more dredging than anticipated to maintain a navigable channel (Kraus *et al* 2008). Further reducing inlet efficiency, the Colorado River was diverted back into Matagorda Bay in 1992 to restore water and sediment flow into the bay. The river diversion project reduced flow rate at the MCR, as well as reducing river sediment delivered to the inlet and adjacent shores. Dredging records from 1990 to 2002 show that an average of 425,000 $m^3$/year were dredged annually to maintain the channel.

Material dredged from the MCR is placed on the shore to the west, down drift. When material is being bypassed, shoreline change adjacent to the inlet is comparable to the historic rates; shoreline position shows slightly greater recession to the west. After routine dredging stopped in 2004, the rate of shoreline recession to the west and advance directly to the east both increased.

Wide spacing of the jetties reduced scouring velocity in the channel and allowed wave penetration over the low weir to mobilize sediments between the jetties. The long and low weir design, coupled with the wide spacing of the jetties, allowed sediment (principally sand) traveling over the weir jetty to be transported along the shoreline behind the impoundment basin. Spit growth fed by sand transported along the shoreline encroached on the navigation channel reducing the amount of material deposited in the impoundment basin and increasing deposition in the channel. In response to growth of the eastern spit, the western shoreline became indented as shown by comparing historical shoreline positions in Figure 4. Figure 5 displays a bathymetric survey conducted in September 2002. The survey shows sediment accumulating behind the weir along the shoreline with the impoundment basin filling from the landward side and the navigation channel filling from the east.

In response to sediment bypassing the impoundment basin, a 150-m long stone sediment training structure (STS) was constructed in 2002 to direct sediment offshore and into the impoundment basin. Figure 6 shows an August 2003 survey, after STS construction and dredging. The figure illustrates the extreme gradient between shallow water near the beach and the impoundment basin. The beach at the MCR is a popular destination for tourists and wade fishermen, but depth and proximity to shore of the impoundment basin created an unsafe environment for wading.

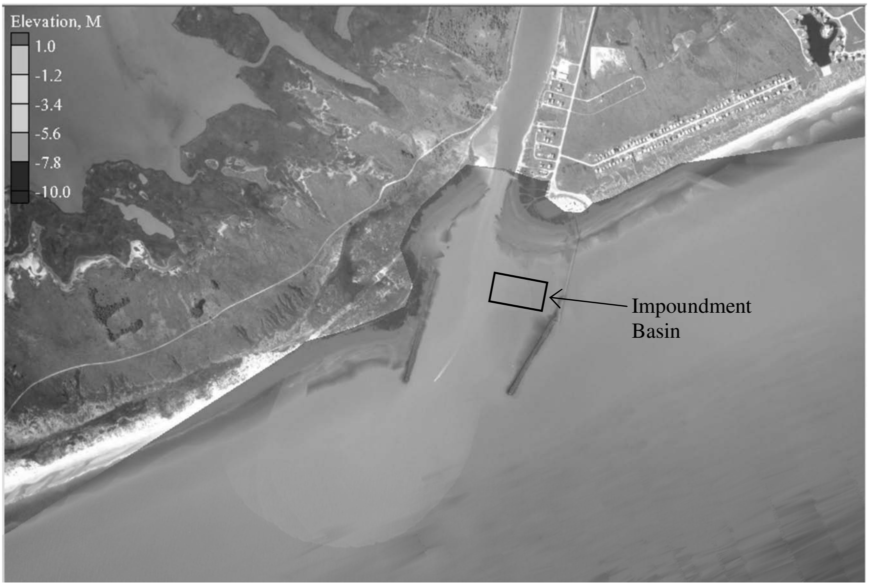


Fig. 5. Bathymetric survey Sep. 2002 (Aerial photograph date: 10/16/2002)

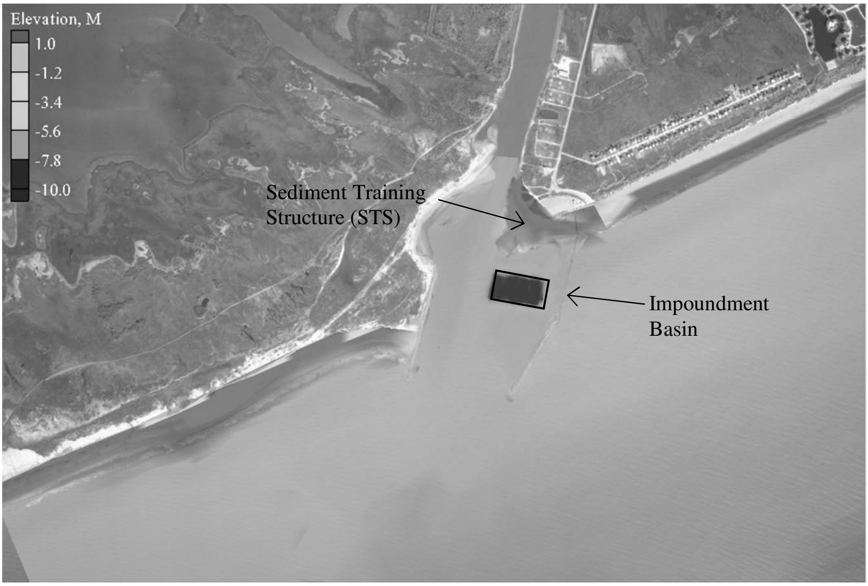


Fig. 6. Bathymetric survey Aug. 2003 (Aerial photograph date: 12/18/2003)

Changes to Federal policy regarding shallow-draft navigation channel maintenance led to cessation of dredging after construction of the STS. Without frequent dredging, it became impossible to maintain shoreline position. Within 2 years, the STS was buried by sand transported along the shore and blown over land, prompting future structures to be designed to higher elevations. Bypassing of sediment around and over the buried STS allowed spit growth to continue, advancing more than 200 m to the west between 2003 and 2006. A bathymetric survey conducted in October 2006 is shown in Figure 7, illustrating morphologic response after three years without dredging. In addition to spit growth, the impoundment basin is completely filled, and the channel has realigned to a more shore normal direction.


Fig. 7. Bathymetric survey Oct. 2006 (Aerial photograph date: 12/21/2006)

To improve inlet efficiency and provide a navigable channel with less frequent dredging requirements, a new east jetty was constructed. The new jetty project was completed in November 2010, shown in Figure 8 with recent shorelines overlaid. The design process, documented in Kraus *et al* (2008), resulted in a narrow and deep channel with a new east jetty 150 m east of and parallel to the existing west jetty. The new jetty was designed to be connected to the existing STS, and crest elevation of both the STS and landward portion of the new jetty were raised to reduce wind-blown transport of sediment over the structure. The plan also included analysis of shoreline change for the new project, which

indicated that bypassing 300,000 $m^3$ every 2 years from east to west would be required to maintain adjacent shoreline position.

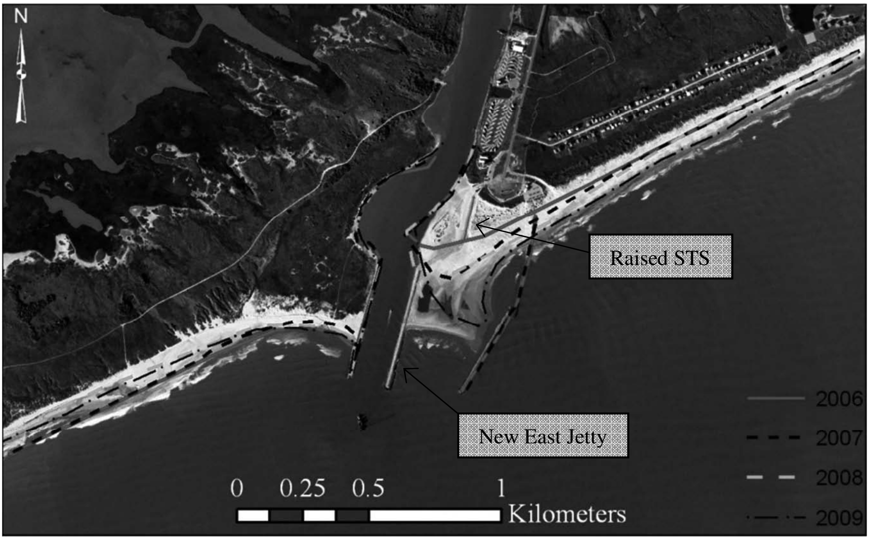


Fig. 8. MCR shoreline position 2006 – 2010 (Aerial photograph date: 11/16/2010)

Channel condition surveys conducted in March 2009 and September 2010 were compared to assess channel morphology during construction, prior to channel dredging. Near the trunk of the west jetty, channel depth increased as much as 1.2 m to a maximum of 4.0 m Mean Low Tide (MLT – a local navigation datum); depth was greatest near the west jetty, transitioning to emergent beach within the authorized channel. At the midpoint of the jetty channel, depth had increased by 1.0 m; depth on the western side of the channel was about 1.0 m deeper than the east. Beyond the seaward end of the jetty in progress, survey data show continued channel shoaling. Field observations indicated that the deepest part of the channel was located directly adjacent to the west jetty; however; condition surveys do not extend all the way to the edge of the jetty to enable quantitative comparison.

The condition survey data indicate that increased inlet current velocity started to naturally scour a new channel along the west jetty after construction of the new jetty began. The new channel was narrow and deep immediately adjacent to the west jetty, following observations at other inlets described in Kieslich (1981). The channel did not reach its authorized depth of 4.57 m MLT and width of 45.7 m without dredging; however, the channel was deep and wide enough to

allow the commercial shrimping fleet access to the Gulf. The channel was dredged to authorized dimensions in December 2010.

Initial observations indicate that the new jetty configuration is more efficient than the weir jetty system and will likely require less frequent dredging than the previous system. Ebb shoal formation has not yet been verified, but its presence may be assumed as judged from the patterns of sediment plumes and wave breaking in aerial photographs. A bathymetric survey is planned to investigate ebb shoal development. Periodic collection of aerial photographs will also continue to monitor inlet response to the new jetty configuration.

**Summary and Conclusions**

The following summary and conclusions are offered as an example of inlet processes, management, and design for a shallow-draft navigation channel on the Texas coast.

- The Mouth of Colorado River was initially stabilized with a weir jetty system, including an impoundment basin, in 1984.
- The weir jetty system proved to be inefficient, because:
    - The weir section was too long and low, allowing more transport into the inlet than anticipated.
    - The jetties were built too far apart, allowing wave energy to mobilize sediment along the shore and from the impoundment basin.
    - The impoundment basin location, coupled with issues noted above, allowed sediment to bypass the basin, forming a spit that migrated into the navigation channel.
    - Dredging requirements were twice those planned, ultimately leading to closure of the channel after maintenance funding was reduced.
- Placing dredged material on the shore to the west successfully maintained historical shoreline change rates adjacent to the inlet until interruption of dredging activities in 2003.
- A sediment training structure (STS) was constructed in 2003 to direct sediment into the impoundment basin.
    - The STS was buried within 2 years by sediment transported along shore and over land, prompting future structures to be designed to higher elevations.

- A new east jetty was constructed in November 2010, improving inlet efficiency and reducing the frequency of required maintenance dredging:
  - Initial observations indicate that the new design is more efficient than the weir jetty design in providing a narrow entrance and stronger scouring inlet current.
  - Inlet currents were sufficient to scour a navigable channel along the west jetty during construction, prior to dredging.
  - Ebb shoal formation has yet to be directly verified; a bathymetric survey is planned to investigate this.
  - Aerial photography and condition surveys are planned for continued monitoring of the inlet.

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**References**

Gibeaut, J.C., White, W.A., Hepner, T., Gutierrez, R., Tremblay, T.A., Smyth, R., and Andrews, J. (2000). “Texas Shoreline Change Project, Gulf of Mexico Shoreline Change from the Brazos River to Pass Cavallo,” *Report to Texas Coastal Coordination Council Pursuant to NOAA Award No. NA870Z0251*, Bureau of Economic Geology, Austin, TX.

Kieslich, J.M. (1981). “Tidal Inlet Response to Jetty Construction,” *GITI Report No. 19*, U.S. Army Coastal Engineering Research Center, Fort Belvoir, VA.

Kraus, N. C. (2007). “Coastal Inlets of Texas,” *Proceedings Coastal Sediments ’07*, ASCE Press, Reston, VA, 1475-1488.

Kraus, N.C., Lin, L. (2002). “Coastal Processes Study of San Bernard River Mouth, Texas: Stability and Maintenance of Mouth,” *ERDC/CHL TR-02-10*, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory.

Kraus, N.C., Lin, L., Smith, E.R., Heilman, D.J., and Thomas, R.C. (2008). “Long-Term Structural Solution for the Mouth of Colorado River

Navigation Channel, Texas," *ERDC/CHL TR-08-4*, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory.

Morton, R. A., Pieper, M. J., and McGowen, J. H. (1976). "Shoreline changes on Matagorda Peninsula (Brown Cedar Cut to Pass Cavallo): An analysis of historical changes of the Texas Gulf shoreline," *Geological Circular* 76-6. Austin, TX: The University of Texas at Austin, Bureau of Economic Geology, 50 p.

U.S. Army Corps of Engineers. (1977). "Mouth of Colorado River, Texas, Phase I: General design memorandum (Navigation Features)," Galveston, TX: U.S. Army Engineer District, Galveston.